Title of Project : Topological Quantum Phenomena in Condensed Matter with Broken Symmetries

Term of Project : FY2010-2014

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【Purpose of the Research Project】

The purpose of this project is to investigate novel quantum phenomena characterized by topology in a variety of condensed matter systems with broken symmetries, such as superconductors, superfluids, and insulators.

The physical systems investigated in this project are those superconductors and superfluids for which symmetry breaking in the "BULK" itself contains important outstanding issues, and furthermore their surfaces and boundaries, which we designate as "EDGES", act as stages where novel topological phenomena emerge.

【Content of the Research Project】

The main physical systems we focus on in the core programs are as follows.

A. Superconductors with broken time-reversal symmetry:

Determination of the vector order parameter of ruthenate superconductors. Demonstration of proximity effects originating from odd-frequency superconductivity specific to junctions involving systems with broken time-reversal symmetry.

B. Spin-triplet superfluids:

Demonstration of intrinsic angular momentum and the associated edge mass current of superfluid ^{3}He-A phase. Elucidation of Andreev surface bound states in various phases of superfluid ^{3}He

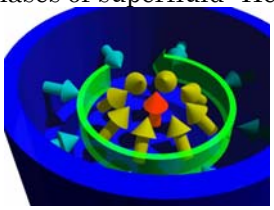

Figure 1. The intrinsic angular momentum of superfluid ^{3}He

C. Superconductors and insulators with broken inversion symmetries.

Elucidation of singlet-triplet mixing and the roles of spin-orbit interaction in non-centrosymmetric superconductors and electric-field-induced surface superconductors. Demonstration of helical edge state in topological insulators.

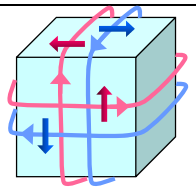

Figure 2. Edge spin currents expected on the surface of a topological insulator.

D. Theories of quantum phenomena in topological condensates.

Establishing unified treatment of spontaneous flows of charge, mass, and spins at the edges of quantum condensate systems with broken symmetries. Deepening the systematic understanding of quasi-particle excitations at the edge, thereby elucidating the universal mathematical structure underlying the topological quantum phenomena.

To accomplish these goals, intimate collaborative and interdisciplinary studies will be conducted on a number of key phenomena and features such as "spin-triplet pairing", "edge currents", and "importance of spin-orbit interactions". To cultivate young researchers, we operate programs such as exchange stay programs and international workshops organized by young researchers.

【Expected Research Achievements】

It is our aim that after five years of intensive efforts in this project, "topological quantum physics" is widely recognized as a key universal approach to describe a wide variety of phenomena in condensed matter. It is envisaged that this approach is not only valuable for the basic understanding of matter but also important for future devices utilizing topological quantum phenomena.

【Key Words】

Topology: An area in mathematics concerned with spatial properties that are preserved under continuous deformations of objects.

【Homepage Address】

http://www.topological-qp.jp/